International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-13 Issue-2, July 2024

Seismic Risk, Urbanization And Prevention, Case of Gjilan City

Shemsi Mustafa, Visar Krelani

Abstract: ***Seismic risk is one of the greatest threats facing our country, Kosovo. The Gjilan region is considered one of the most at-risk areas in the country. In the past, the Gjilan region has been struck hundreds of times by earthquakes with magnitudes ranging from 2.0 to 6.1, and these seismic events attest to the seismic risks for the region, also based on the Gjilan fault which extends southwest-northeast. Urban areas in the territory of Kosovo, including the city of Gjilan, are experiencing extreme urban transformation, and the urbanization process since independence in 1999 has not been taken seriously, considering the seismic risk factor. The current study does not include comprehensive research on the seismic risk of the region of Gjilan, but for some urban areas of the city of Gjilan, and evaluates the analysis resulting from geophysical studies in several locations with seismic acceleration parameters concerning risk prevention, that is urban areas with all parameters for designs, creating security for the lives of citizens.***

Keywords: Seismicity, Tectonics, Urbanism, Seismic Risk

I. INTRODUCTION

The threat from disaster or risk is a natural event, process, or occurrence with the potential to cause loss in human lives, their well-being, and their environment. In other words, it is a source of overall risk.

Geographically, Kosovo is located in the contact zone of two major tectonic plates, on one side the African plate pushes against the Euro-Asian plate, and stands on its foundation. For these reasons, countries in the Mediterranean zone, including the surrounding areas, belong to regions with high seismic risk. [1], [2], [3], [16].

Kosovo represents an active seismic zone. In the territory of Kosovo, there are many sources of seismic activity, which include faults or active fault zones responsible for earthquakes. [6][22]. These active faults, which extend deep underground, are where earthquakes originate, particularly in the so-called seismotectonic nodes, where the intersections of active faults with different orientations occur, and where strong earthquakes are expected to originate. [4], [8].

Manuscript received on 30 June 2024 | Revised Manuscript received on 10 July 2024 | Manuscript Accepted on 15 July 2024 | Manuscript published on 30 July 2024.

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Based on the sources of the seismological network of Kosovo and the surrounding regions, a new catalog for the territory of Kosovo was compiled, including around 214 events with a magnitude of M≥3.5 from 1456 to 09/31/2023. These events have shallow foci, generated in the Earth's crust, at a maximum depth of 15-25 km underground. Only two earthquakes occurred before 1920 [7]. Seismicity and data integration on the seismic risk map for the territory of Kosovo, return period 475 years (Table 1, Figure 1). [9], [10].

Table 1. Intensity and Number of Earthquakes, Period 1456-2023

Nr. quake.	115	60	22	11	3	3
Magnitude	3.5-3.9	4.0 - 4.4	4.5 - 4.9	5.0 - 5.4	5.5 - 5.9	6.0 - 6.2
Intensity	4.16-4.83	5.0 - 5.66	5.83 - 6.5	6.6 - 7.33	7.5 - 7.6	8.73 – 9.0

The scale of seismic studies will never be at the optimal level, as it must be considered that each new earthquake that strikes the territory will bring new data to supplement the existing information.

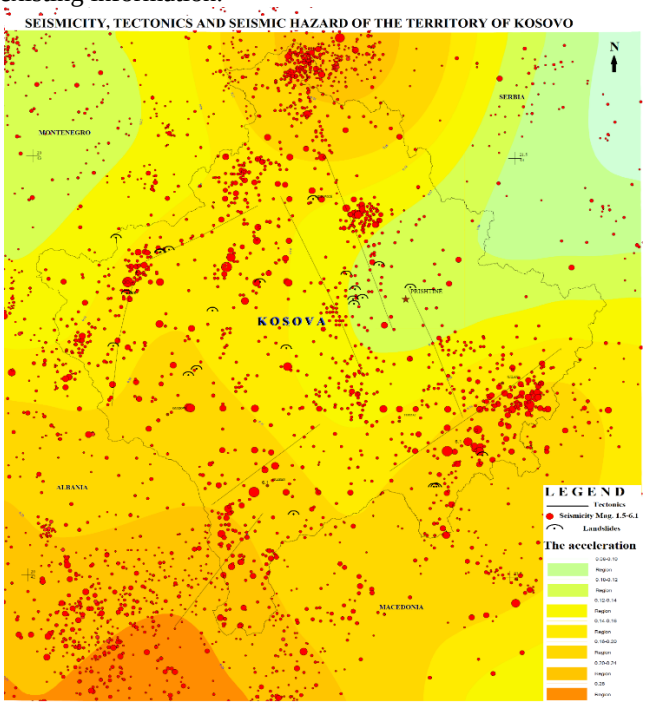

Fig. 1 Seismicity, Active Fault, and Data Integration on The Seismic Risk map for the Territory of Kosovo, Return Period 475 Years

Risk prevention constitutes one of the most important actions in urban development to ensure the sustainable safety of users' lives, reduce economic losses, and decrease the likelihood of structural functionality loss after an earthquake.

Since there are still no devices to accurately predict earthquakes in terms of time, location, and magnitude, the fundamental characteristics of seismic risk are determined based on data from past earthquakes and those outside Kosovo's territory that significantly affect our territory. Generally, there is no rule for earthquakes regarding periodicity, but only in terms of the probability of events occurring in a specific place, based on the earthquake catalog and various factors such as tectonic, geological, and topographic elements studied and calculated in the preparation of Seismic Risk maps. As is common practice, the concentration of population and the development of inhabited areas usually occur along rivers or low-lying areas characterized by larger deposits of loose soil layers. In these cases, the seismic acceleration presented in seismic risk maps for rock site conditions is significantly amplified and, as a result, can appear on the surface with entirely modified characteristics (amplitude, frequency, duration).

Many multi-story buildings have been constructed without geological, geophysical, and geomechanical soil studies, a process that is mandatory in many places. Ignoring this procedure can lead to unpredictable consequences in the future because many areas in our country are active seismic zones. [5], [7], [13], [14][19][20][21][22].

II. SEISMIC RISK IN GJILAN

A. Geography and Demography of the Gjilan Region

Gjilan region is located in the southeastern part of Kosovo and is one of the seven regions of Kosovo. It includes five municipalities: The Municipality of Gjilan, Kamenica, Vitia, Ranillug, and Partesh, covering over 1,200 km², with a population of approximately 177,000 inhabitants.

The city of Gjilan is divided into two areas according to the number of buildings and with over 54,239 autochthonous inhabitants and over 20,000 who frequent the rural areas and other centers of Kosovo every day, a potential seismic risk from an expected earthquake. [17], [18].

- Zone 1. The number of high-rise, low-rise, and medium-rise buildings and the number of residents are high based on the high attendance.
- Zone 2, is a Suburban zone planned for high-rise buildings with exceptions such as; some commercial buildings and low-rise buildings existing. (Figure 3).

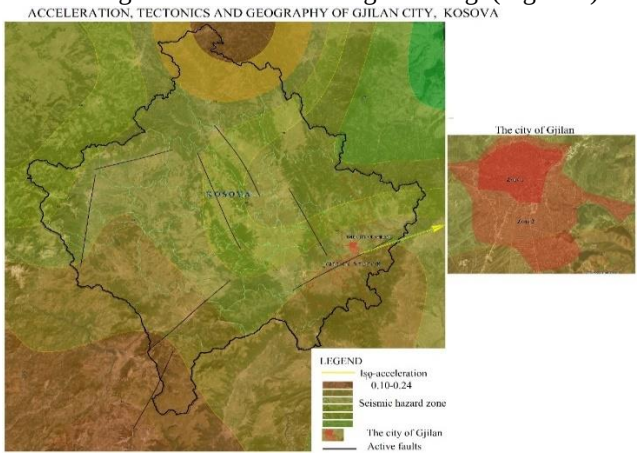

Fig 2 Map of Acceleration, Tectonics, and Geography of Gjilan City in Two-Zone

B. Geological Conditions of the Region

From a geological perspective, the Gjilan region lies in the Vardar Zone, while the eastern part is situated in the Dardan Massif. The geological construction of the Vardar Zone includes magmatic, metamorphic, and sedimentary formations, with ages ranging from Precambrian to Paleozoic, Mesozoic, and up to the Tertiary (Paleogene). Jurassic ophiolites occupy a special place within it [1], [2], [16]. Unconformably over these formations, Tertiary molassic basins, such as that of Skopje, have been deposited, which are filled with Miocene-Pliocene molasses. Quaternary deposits lie discordantly over the Mio-Pliocene molasses, (Figure 3). [15].

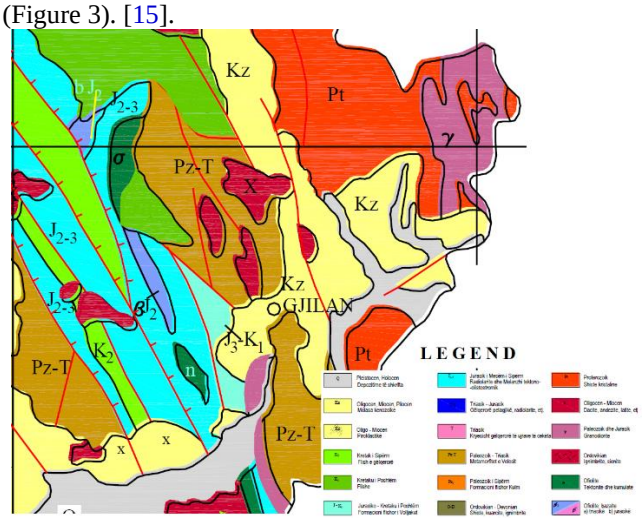

Fig.3 Geological Map of the Gjilan Region

C. History of Seismicity in Gjilan

Compared to other areas of Kosovo, Gjilan represents a region with relatively high seismic activity. It has been struck by strong local earthquakes in the past and may be affected by similar events in the future. Below is the Seismic Risk Map and the seismic activity for the period from 1920 to 2007 with magnitudes ranging from 3.5 to 6.1, as well as the seismic activity for the period from 2008 to 2023 with magnitudes ranging from 1.5 to 5.7. [9], [10], [11], [12]. Along the 63/50/90 normal fault of Gjilan, extending from southwest to northeast in a length of over 45 km, earthquakes with a magnitude of up to 6.1 on the Richter scale were generated. The border of the Gjilan region, signaled on the map in red, which includes several municipalities (Figure 4, Table 2).

Retrieval Number: 100.1/ijrte.B812113020724
DOI: 10.35940/ijrte.B8121.13020724
Journal Website: www.ijrte.org

Published By:
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Table 2 Seismicity for the Period 1920-2023 with Mag. 3.5-6.1 of the Gjilan Region

Seismicity for the Period 1920-2007 with mag. 3.5-6.1 of the Gjilan Region				Seismicity Monitored by the Seismological Network of Kosovo for the Period 2008-2023 with Magnitude 1.5-4.4, of the Gjilan Region		
Nr.earthquake	**Magnitude**	**Intensity**		**Nr.earthquake**	**Magnitude**	**Intensity**
34	3.5-3.9	4.16-4.83		135	1.5 -1.9	1 - 2
19	4.0 - 4.4	5.0 - 5.66		32	2.0 - 2.4	2 - 3
4	4.5 - 4.9	5.83 - 6.5		13	2.5 - 2.9	3 - 3.5
5	5.0 - 5.4	6.6 - 7.33		6	3.0 - 3.4	3.6 - 4.5
2	5.5 - 5.9	7.5 - 7.6		5	3.5 - 3.9	4.16-4.83
1	6.0 - 6.1	8.73 – 9.0		4	4.0 - 4.4	5.0 - 5.66

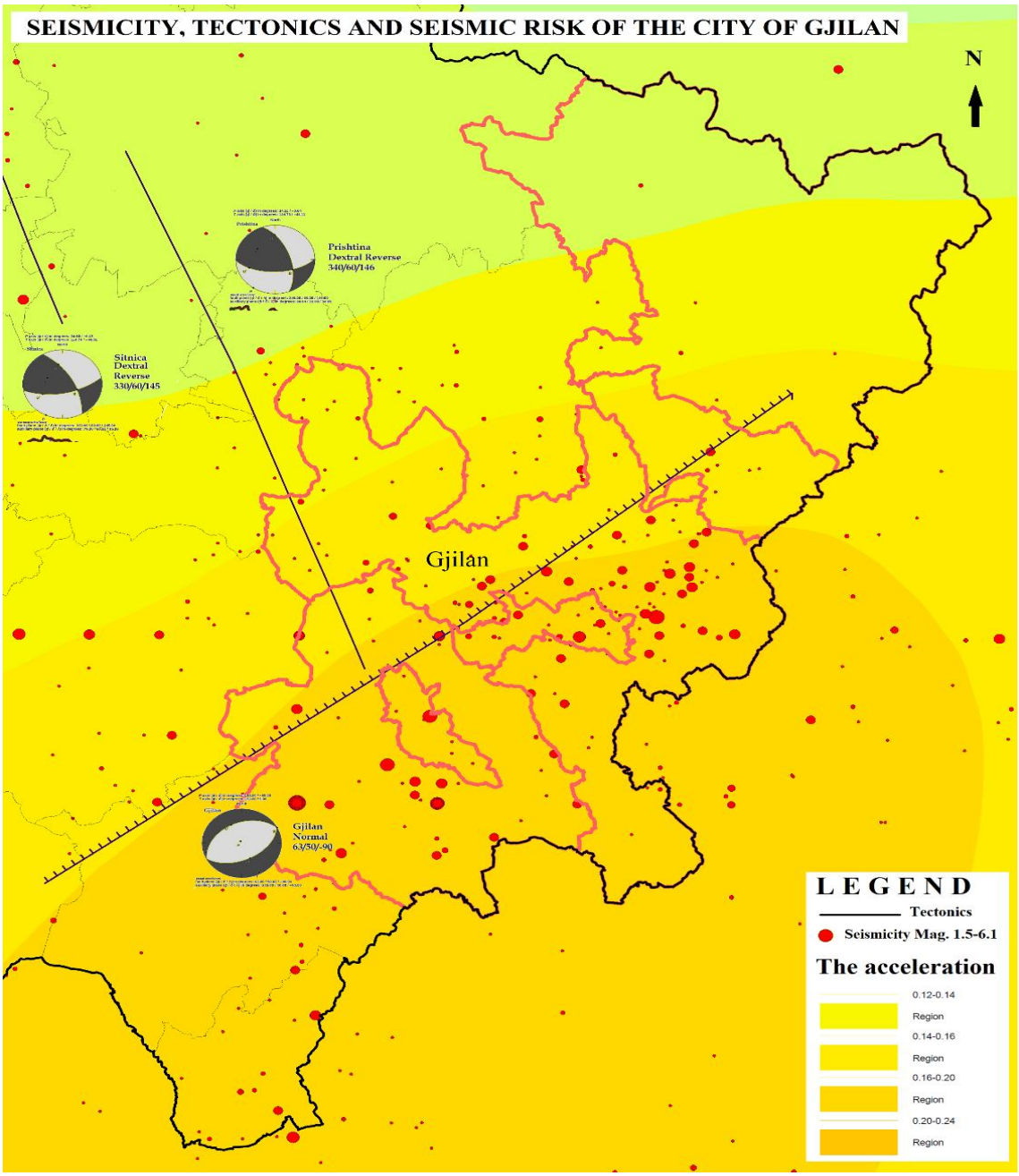

Fig. 4 Map of Seismicity, Tectonics and Seismic Risk of the of Gjilan City

Among the strongest earthquakes in the Gjilan region was one that occurred in 1920 with a magnitude of 6.1 on the Richter scale and an intensity of 8.75 degrees.

As for damages, we have no data from this earthquake.

- **On April 24, 2002, at 12:52 PM (local time)**, a strong earthquake struck the Municipality of Gjilan in Kosovo. The earthquake caused significant damage to buildings, resulting in one death and dozens of injuries. In general, in the City of Gjilan, buildings with reinforced concrete skeletons or mixed constructions, with masonry and reinforced concrete structural elements, generally suffered damage, but only rarely. However, brick masonry buildings from before the 1970s, as well as newer buildings of this structural type, sustained severe damage.

In rural areas, older brick or stone masonry buildings, and quickly erected buildings, especially those on poor or differentiated soil conditions, were heavily damaged. Throughout the entire pleistoseist zone of the April 24, 2002 earthquake, from Gjilan to Zhegër, heavy roofs with tiles were damaged, and chimneys were broken and collapsed.

The data indicate that throughout the rural pleistoseist zone, there was grade 5 damage in rare cases in type A houses, grade 4 damage in a few type A houses and rarely in type B houses, grade 3 damage in many type A houses and rarely in type B houses, and grade 2 damage in most type B houses, while grade 1 damage was very rarely encountered in type C houses, (Figure 5). [15], [17].

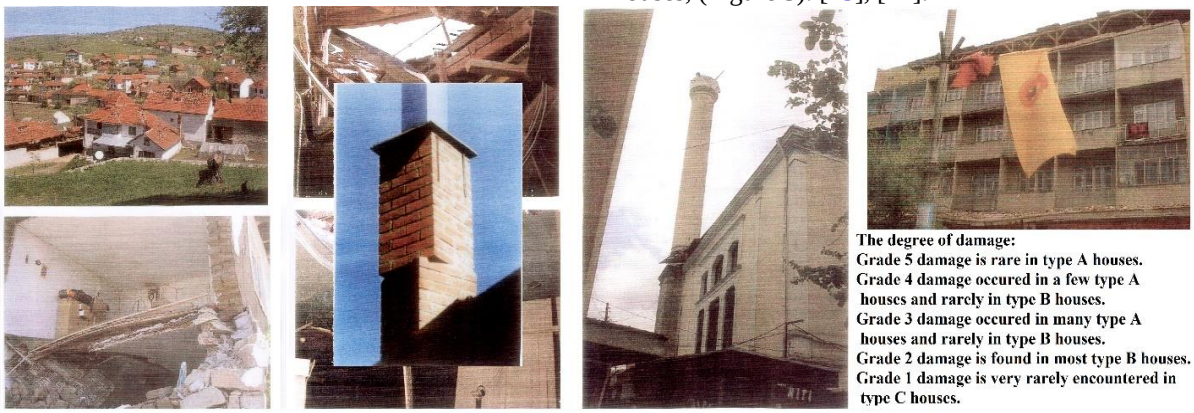

Fig. 5 Data on Grade 5, 4, 3, 2, and 1 Damage in Type A , B and C Structures From the 2002 Gjilan Earthquake

III. SEISMIC RISK OF THE URBANIZATION OF GJILAN CITY, AREA WITH SEISMIC ACTIVITY

Although seismic activity in the Gjilan area is relatively high, the strong effects of earthquakes were not previously considered in the calculation and design of structures, so the first temporary seismic design rule was adopted in the late 1960s. Regarding existing structures, and especially masonry buildings, their risk is greater. Most of these buildings were constructed between 1956 and 1981 without the application of any seismic regulations or by not including the seismic component in the entirety of the first regulation. Older masonry buildings are particularly at risk because, in addition to construction deficiencies, they have been weakened over time due to poor maintenance and material deterioration. Furthermore, many structures in urban areas built in the 20th century have had their basements and ground floors adapted for commercial use, compromising or completely removing load-bearing elements, while rooftop extensions have been added. All these changes were made without any analysis, project, or approval from relevant institutions, making these buildings potentially hazardous in various degrees in the event of future earthquakes. Construction in the early 21st century—As is typical, population concentration and the development of residential areas have usually occurred along rivers or low-lying areas characterized by larger deposits of loose soil layers, (Figure 6).

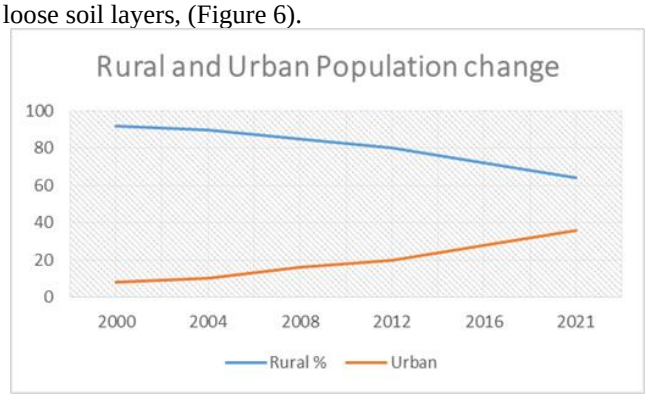

Fig. 6 Graph of Population Displacement from Rural to Urban Areas Per Year

In these cases, the seismic acceleration shown on seismic hazard maps for rock soil conditions is significantly amplified, and as a result, it can present itself on the surface with entirely modified characteristics (amplitude, frequency, duration).

Many multi-story buildings have been constructed without geological, geophysical, and geomechanical soil studies, a process that is mandatory in many countries. Ignoring this procedure can lead to unpredictable consequences in the future because many areas in our country are active seismic zones. [17].

IV. RESULTS: SEISMIC RISK BASED ON GEOPHYSICAL STUDIES FOR URBAN ZONES OF GJILAN CITY

Rapid urban expansion and its irreversible nature pose a real threat to land stability, which is a non-renewable problem.

Therefore, it is urgent to rethink the city and land management with additional geological engineering, geophysical, and geotechnical soil studies, rules for aseismic constructions, and contemporary laws and regulations for constructions according to Eurocode 8, within the framework of medium- and long-term strategy for urban planning.

Choosing locations in a suitable area with proper foundations, by implementing mandatory measures according to preventive and recommended criteria, will reduce or limit damage in the event of an earthquake. Since there is currently no reliable means for predicting earthquakes, prevention is the only effective way to protect against them.

a. Implementation of Micro-Zoning Studies for each City (Urban Area) and for Special Importance Structures

These measures must necessarily be accompanied by preparatory measures and actions aimed at the framework of the national policy for the regulation and sustainable development of the Gjilan city.

Retrieval Number: 100.1/ijrte.B812113020724
DOI: 10.35940/ijrte.B8121.13020724
Journal Website: www.ijrte.org

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In seismic micro hazard zonation, criterium to quantify the spatial variation of the subsurface response on a specific design earthquake that can be expected in the area (e.g. the earthquake with a return period of 475 years in the European Seismic Code EC-8). Seismic microzonation requires a multidisciplinary approach with major contributions from geology, seismology, and geotechnical engineering. Earthquake ground motions are affected by several factors such as source, path, and side effects. An assessment of ground motion therefore depends on the regional seismicity, attenuation of ground motion intensity, and local site effects on ground motion (Manual for zonation on seismic geotechnical hazards TC4, 1999). Earthquake hazard zonation for urban areas, mostly referred to as seismic microzonation, is the first and most important step toward a seismic risk analysis and mitigation strategy in densely populated regions. As previously mentioned, for the urban zones of Gjilan, a comprehensive GIS-based methodology for seismic microzonation is applied. (Figure 7).

b. Geological and Geotechnical Structure of the Urban Zone

The geological and geomechanical characteristics of the surface layers are the basic factors in seismic macrozoning.

The urban area of Gjilan is located in the southeast part of Kosovo. From a geological point of view, the Gjilan area is characterized by a variety of geological formations. Among these are rocks ranging from Neoproterozoic to Quaternary age comprising sedimentary and magmatic types together with rather less frequent metamorphic rocks.

Earthquake hazard zonation for urban areas, mostly referred to as seismic microzonation, is the first and most important step toward a seismic risk analysis and mitigation strategy in densely populated regions. In seismic micro hazard zonation, one would like to quantify the spatial variation of the subsurface response on a typical earthquake that can be expected in the area. To quantify the expected ground motion, we have to determine how the seismic signal is propagating through the subsurface.

Propagation is particularly affected by the local geology and the geotechnical ground conditions. Large amplification of the seismic signals generally occurs in areas where layers of low seismic velocity overlie material with high seismic velocity, i.e. where soft sediments cover bedrock or more stiff soils. Therefore, it essential here is to obtain a good understanding of the local subsurface conditions. Geotechnical profiles for nine urban areas of Gjilan city, (Figure 7).

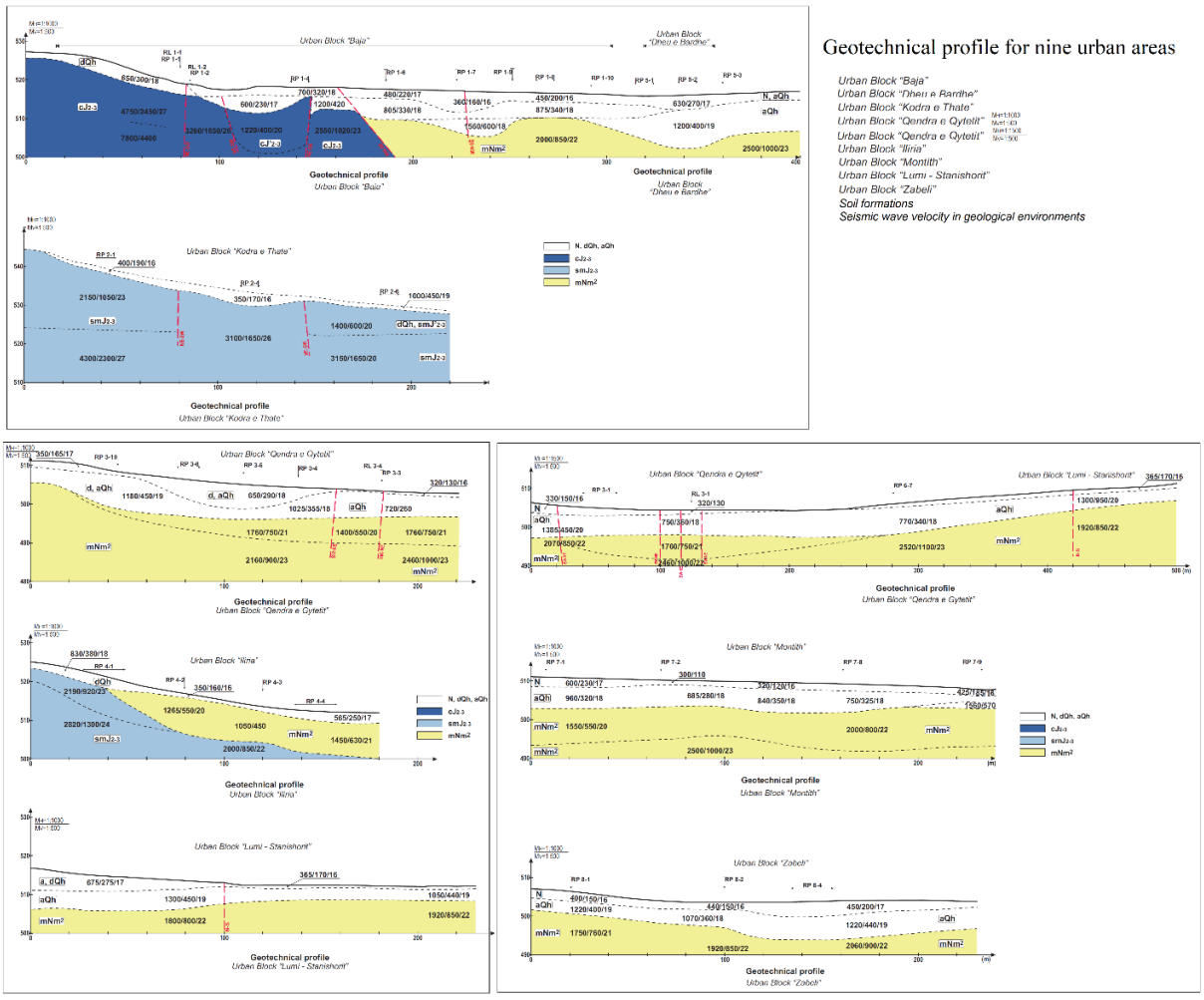

Fig. 7 Geotechnical Profiles for Nine Urban Areas of the Gjilan City

c. Zonation Maps

In the framework of this study digital map has been developed representing the seismic potential of selected urban zones in Gjilan city, two other maps are given presenting all selected locations on the urban zones of the Gjilan city with acceleration distribution for DLR I NCR, EC8 requirements.

Presented seismic parameters in digital maps are very good input layers to City decision-makers for developing the general urban plan of the Gjilan city and upgrading detailed urban plans for location.

Digital maps are developed for all locations presenting the following seismic parameters:

- Spatial distribution of maximum acceleration at foundation depth (-2.0 m) for Damage Limitation Requirements, TDLR 95 years, (Figure 8).

Fig. 8 Spatial Distribution of Maximum Acceleration at Foundation Depth (-2.0 m) TDLR 95 Years

- Spatial distribution of maximum acceleration at foundation depth (-2.0 m) for Non-Collapse Requirements, TNCR 475 years (Figure 9).

Fig. 9 Spatial Distribution of Maximum Acceleration at Foundation Depth (-2.0 m) TNCR 475 Years

Retrieval Number: 100.1/ijrte.B812113020724
DOI: 10.35940/ijrte.B8121.13020724
Journal Website: www.ijrte.org

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V. CONCLUSIONS AND RECOMMENDATIONS

Based on the results from extensive in-situ investigations and results from comprehensive cabinet work (numerical analysis, mapping) the following conclusions can be given:

- Applied methodology in this project is based on a multidisciplinary approach that considers regional seismological and tectonic characteristics of the wider region of Gjilan, analysis of seismic hazards, and geophysical and engineering-geological characteristics of the selected locations of Gjilan urban area.
- In-situ investigations consisting of geophysical surveys and geotechnical investigations provided data for the definition of the local geological characteristics for the investigated urban blocks in Gjilan. The reflection investigations proved the presence of three dominant geological media down to a depth of about 200 m:

– Quaternary and loosened Miocene sediments down to the depth of 20-30 m,

- undisturbed Miocene sediments down to the depth of about 100-160 m and

- Jurassic meta-carbonate and rocks of tectonic melange that are situated below the Quaternary and Miocene ones. Faults stretching NW-SE NE-SW and E-W have also been defined.

- The amplifying medium of the sites in investigated urban blocks in Gjilan is represented by Quaternary and degraded Miocene and Jurassic layers to the depth of 10-30m characterized by seismic velocities Vs < 750m/s. The undisturbed layers lying underneath with Vs > 800m/s are regarded as seismic bedrock for the models. In general, regarding the amplifying soil deposits the investigated urban zones in Gjilan can be considered as shallow (most of them) to medium deep deposits.
- Based on the available data analysis of seismic hazard was performed. Determined seismic parameters for Gjilan were used in further seismic site response analysis for two return periods recommended in EC8, part 1 (95 and 475 years return periods).
- Classification of ground conditions was done based on the recommendation given in EC8, Part 1. The results from geophysical measurements of seismic waves showed that all the investigated locations can be classified as type “B”. Some minor exceptions can be observed at locations of former and existing river channels where the ground conditions are between type “B” and type “C”. [6]
- Presented seismic parameters in digital maps are very good input layers to City decision-makers for developing the general urban plan of Gjilan and upgrading detailed urban plans for each location.

In conclusion, much needs to be done regarding construction safety in our country,

Every construction, depending on its purpose, must meet the basic requirements for construction as outlined by urban planning parameters the documentation of the state or local urban plan, or the infrastructure project and other conditions defined by law and specific laws.

Construction must be designed and executed in such a way that during construction work and usage, there will be no disruption of mechanical resistance, stability, and seismic protection. The level of mechanical resistance, stability, and seismic protection of the building must be ensured by the contractor during and after the construction of the entire structural system.

Compliance with these parameters will directly impact three aspects:

- Ensuring the safety of citizens,
- Reducing economic losses, and
- Reducing the likelihood of loss of functionality of structures after an earthquake.

DECLARATION STATEMENT

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of my knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have equal contributions.

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